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(54) **PLASMA-BASED CHEMICAL SOURCE DEVICE AND METHOD OF USE THEREOF**

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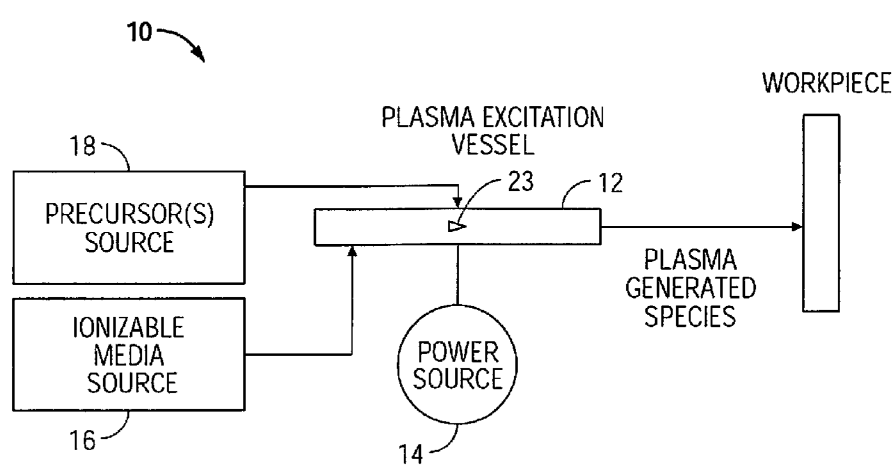

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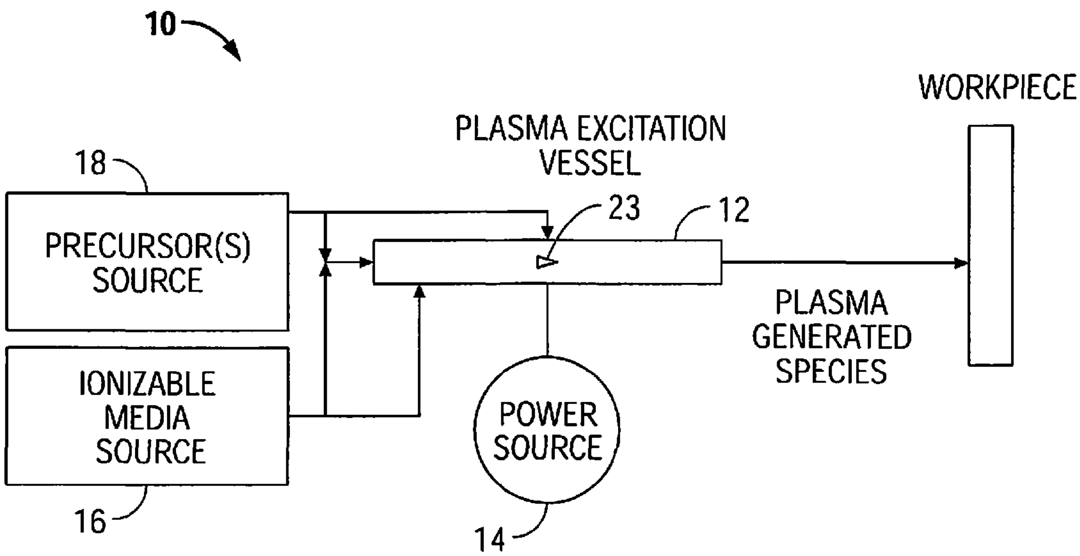
(57) **ABSTRACT**

The present disclosure provides for a plasma system including a plasma device coupled to a power source, an ionizable media source and a precursor source. During operation, the ionizable media source provides ionizable media and the precursor ionizable media source provides one or more chemical species, photons at specific wavelengths, as well as containing various reactive functional groups and/or components to treat the workpiece surface by working in concert for synergetic selective tissue effects. The chemical species and the ionizable gas are mixed either upstream or midstream from an ignition point of the plasma device and once mixed, are ignited therein under application of electrical energy from the power source. As a result, a plasma effluent and photon source is formed, which carries the ignited plasma feedstock and resulting mixture of reactive species to a workpiece surface to perform a predetermined reaction.

14 Claims, 6 Drawing Sheets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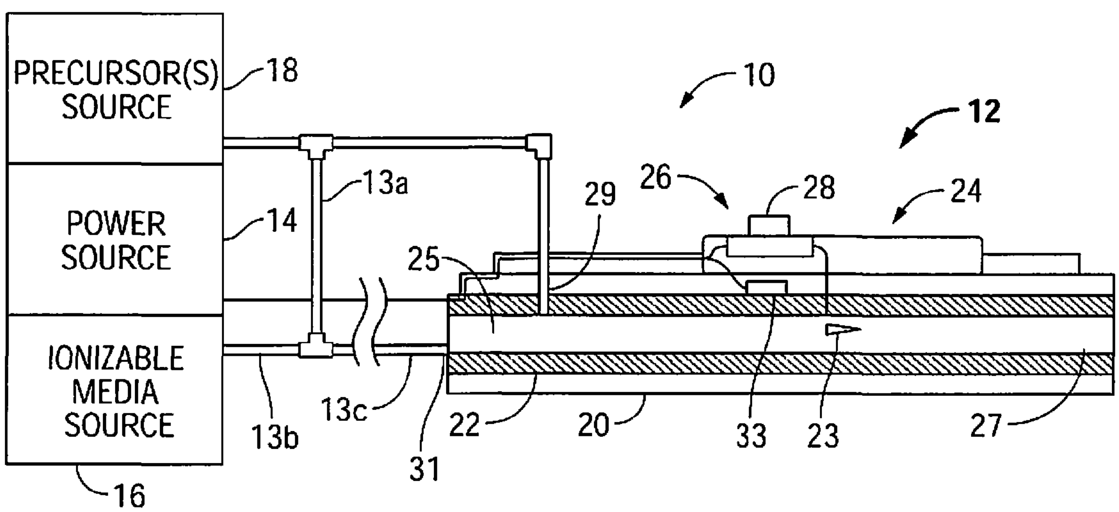
IONIZABLE
MEDIA
SOURCE
POWER
SOURCE
16
14

FIG. 1A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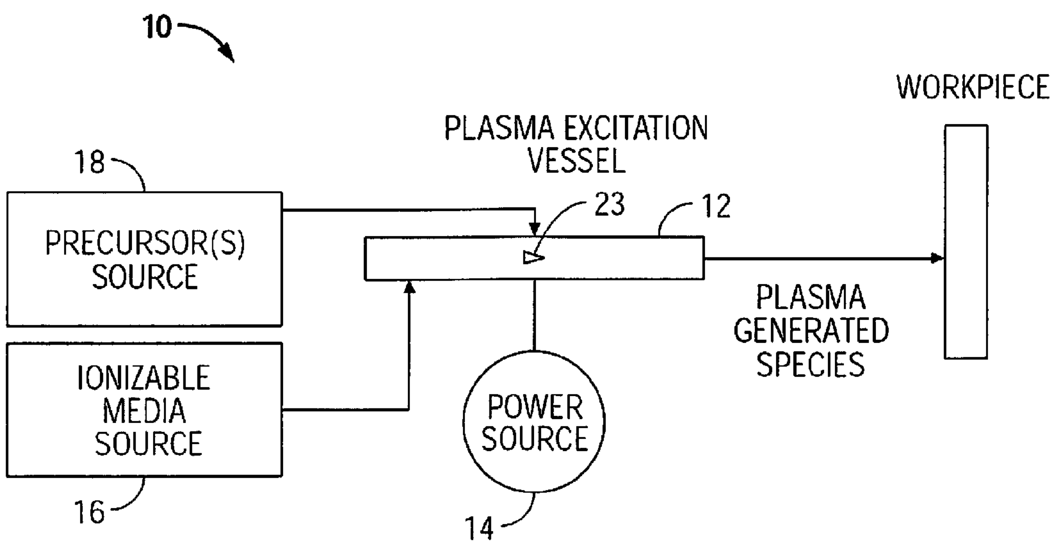
13b
13c
22
20
33
23
27
31
16

FIG. 2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VESSEL
18
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PLASMA
GENERATED
SPECIES
IONIZABLE
MEDIA
SOURCE
POWER
SOURCE
16
14

FIG. 1B

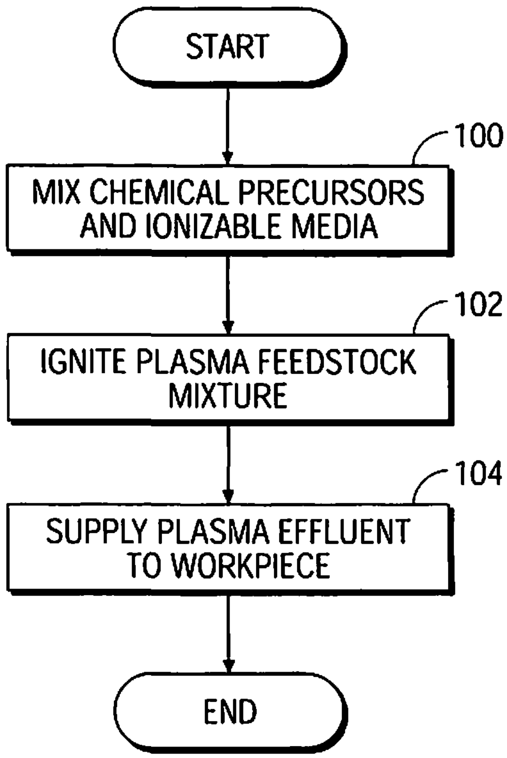
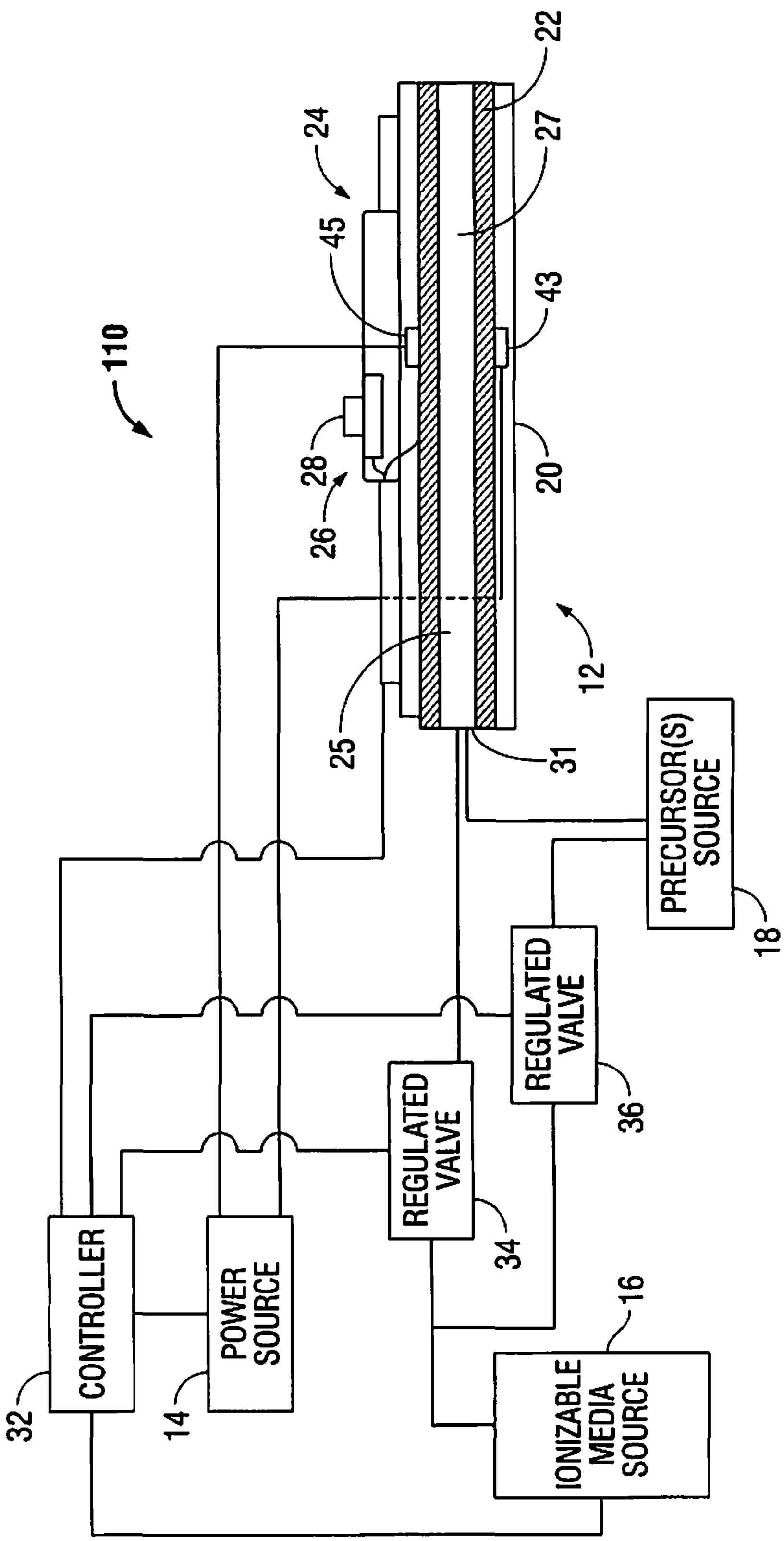

START
100
MIX CHEMICAL PRECURSORS AND IONIZABLE MEDIA
102
IGNITE PLASMA FEEDSTOCK MIXTURE
104
SUPPLY PLASMA EFFLUENT TO WORKPIECE
END

FIG. 3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22
24
27
45
43
28
26
20
12
25
31
CONTROLLER
POWER SOURCE
REGULATED VALVE
REGULATED VALVE
PRECURSOR(S) SOURCE
IONIZABLE MEDIA SOURCE
32
14
34
36
18
16

FIG. 4

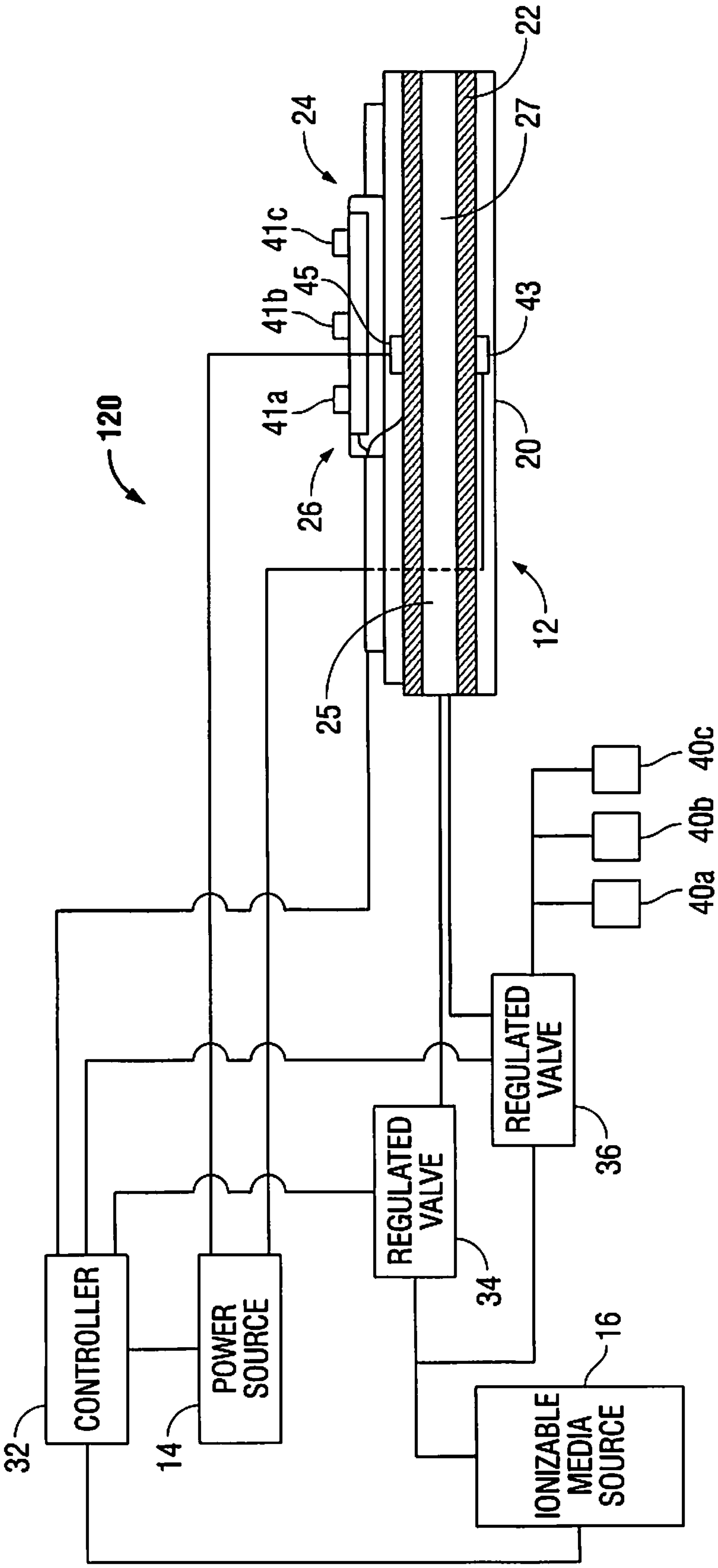
120
24
22
27
26
41a
41b
41c
45
43
20
12
25
CONTROLLER
32
POWER SOURCE
14
REGULATED VALVE
34
REGULATED VALVE
36
IONIZABLE MEDIA SOURCE
16
40a
40b
40c

FIG. 5

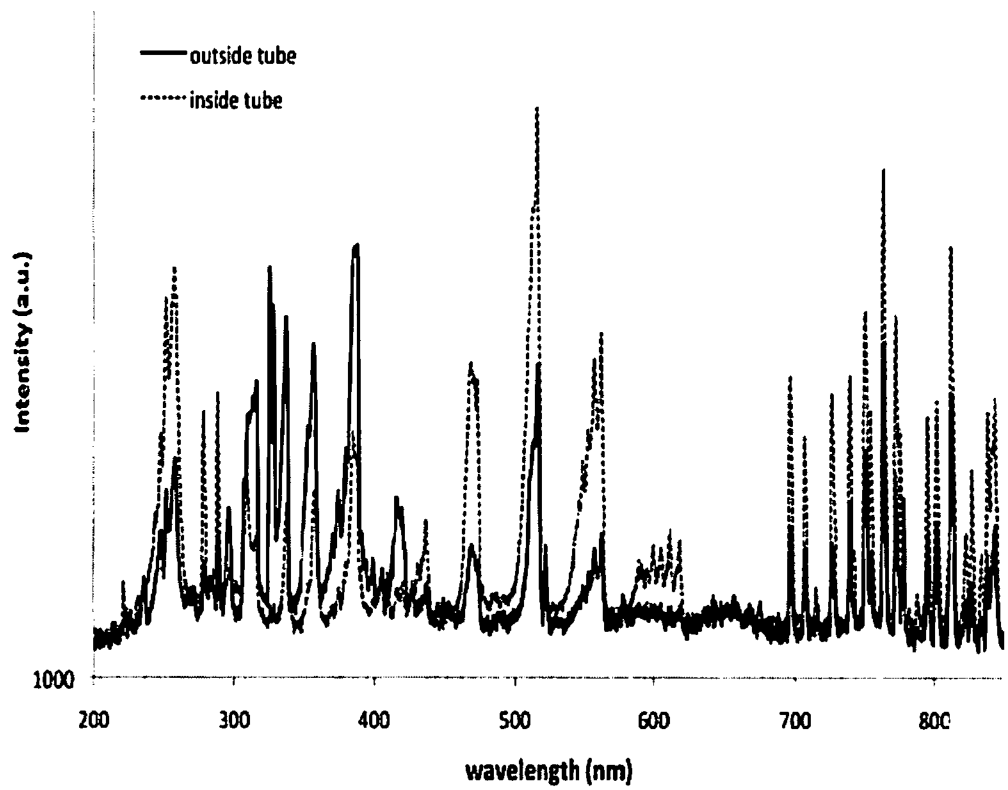
outside tube
inside tube
Intensity (a.u.)
1000
200
300
400
500
600
700
800
wavelength (nm)

FIG. 6

PLASMA-BASED CHEMICAL SOURCE DEVICE AND METHOD OF USE THEREOF

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims the benefit of and priority to U.S. Provisional Application Ser. No. 61/057,667 entitled "PLASMA-BASED CHEMICAL SOURCE DEVICE AND METHOD OF USE THEREOF" filed by Moore et al. on May 30, 2008, the entire contents of which are incorporated by reference herein.

BACKGROUND

1. Technical Field

The present disclosure relates to plasma devices and processes for surface processing and material removal or deposition. More particularly, the disclosure relates to an apparatus and method for generating and directing chemically reactive plasma-generated species in a plasma device along with excited-state species (e.g., energetic photons) that are specific to the selected ingredients.

2. Background of Related Art

Electrical discharges in dense media, such as liquids and gases at or near atmospheric pressure, can, under appropriate conditions, result in plasma formation. Plasmas have the unique ability to create large amounts of chemical species, such as ions, radicals, electrons, excited-state (e.g., metastable) species, molecular fragments, photons, and the like. The plasma species may be generated in a variety of internal energy states or external kinetic energy distributions by tailoring plasma electron temperature and electron density. In addition, adjusting spatial, temporal and temperature properties of the plasma allows for achieving specific changes to the material being irradiated by the plasma species and associated photon fluxes. Plasmas are also capable of generating photons including energetic ultraviolet photons that have sufficient energy to initiate photochemical and photocatalytic reaction paths in biological and other materials that are irradiated by the plasma photons.

SUMMARY

Plasma has broad applicability to provide alternative solutions to industrial, scientific and medical needs, especially workpiece surface processing at low temperature. Plasmas may be delivered to a workpiece, thereby affecting many changes in the properties of materials upon which they impinge. One suitable application of the unique chemical species that are produced is to drive non-equilibrium or selective chemical reactions at the workpiece. Such selective processes are especially sought in biological tissue processing, which allows for cutting and removal of tissue at low temperatures with differential selectivity to underlayers and adjacent tissues. That is, the plasma may remove a distinct upper layer of a workpiece but have little or no effect on a separate underlayer of the workpiece or it may be used to selectively remove a particular tissue from a mixed tissue region or selectively remove a tissue with minimal effect to adjacent organs of different tissue type. More specifically, the plasma species are capable of modifying the chemical nature of tissue surfaces by breaking chemical bonds, substituting or replacing surface-terminating species (e.g., surface functionalization) through volatilization, gasification or dissolution of surface materials (e.g., etching). By proper choices of conditions one can remove a tissue type entirely but not effect a nearby different tissue type at all when selectivity of the plasma chemistry is tailored to be high.

In one aspect, the present disclosure provides for a plasma system including a plasma device coupled to a power source, an ionizable media source and a precursor source. During operation, the ionizable media source provides ionizable media suitable for plasma initiation and maintenance and the precursor source provides one or more chemical species having various reactive functional groups and/or components that are desired for surface treatment. The chemical species and the ionizable media are mixed upstream or at ignition point of the plasma device and, once mixed, are ignited under application of electrical energy from the power source. The ignited media forms a volume of active plasma in the region where electrical energy is delivered. The active plasma volume includes various species that flow therefrom as an effluent that is delivered to a workpiece. Alternatively the species and the ionizable media may be excited separately (e.g., one excited upstream and another added midstream or downstream, which are then combined prior to delivery to a workpiece).

According to one embodiment of the present disclosure, a plasma system is disclosed. The system includes a plasma device having an active electrode and an ionizable media source configured to supply ionizable media to the plasma device. The ionizable media source is coupled to the plasma device at a first connection upstream of the active electrode. The system also includes a precursor source configured to supply at least one precursor feedstock to the plasma device. The precursor source is coupled to the plasma device at a second connection at the active electrode or upstream thereof. The system further includes a power source coupled to the active electrode and configured to ignite the ionizable media and the precursor feedstock at the plasma device to form a plasma volume.

A method for generating plasma is also contemplated by the present disclosure. The method includes the steps of: supplying ionizable media to a plasma device, supplying at least one precursor feedstock to the plasma device at the active electrode or upstream thereof and igniting the ionizable media and the precursor feedstock at the plasma device to form a plasma effluent.

According to another embodiment of the present disclosure, a plasma system is disclosed. The system includes a plasma device having an active electrode and an ionizable media source configured to supply ionizable media to the plasma device. The ionizable media source is coupled to the plasma device at a first connection upstream of the active electrode. The system also includes a plurality of precursor sources, each of the precursor sources is configured to supply at least one precursor feedstock to the plasma device. Each of the precursor sources is also coupled to the plasma device at a second connection at the active electrode or upstream thereof. The system also includes a power source coupled to the active electrode and configured to ignite the ionizable media and the precursor feedstock at the plasma device to form a plasma volume.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of this specification, illustrate exemplary embodiments of the disclosure and, together with a general description of the disclosure given above, and the detailed description of the embodiments given below, serve to explain the principles of the disclosure, wherein:

FIG. **1**A is a schematic diagram of a plasma system according to the present disclosure;

FIG. **1**B is a schematic diagram of another embodiment of a plasma system according to the present disclosure;

FIG. **2** is a schematic diagram of a plasma system and a plasma handpiece according to one embodiment of the present disclosure;

FIG. **3** is a flow diagram of an illustrative method according to the present disclosure;

FIG. **4** is a schematic diagram of a plasma system and a plasma handpiece according to one embodiment of the present disclosure;

FIG. **5** is a schematic diagram of a plasma system and a plasma handpiece according to another illustrative embodiment the present disclosure; and

FIG. **6** is spectra graph of a plasma generated according to one illustrative embodiment of the present disclosure.

DETAILED DESCRIPTION

Plasmas are commonly generated using electrical energy that is delivered as either direct current (DC) electricity or electricity that is alternating current (AC) at frequencies from about 0.1 hertz (Hz) to about 100 gigahertz (GHz), including radio frequency ("RF", from about 0.1 MHz to about 100 MHz) and microwave ("MW", from about 0.1 GHz to about 100 GHz) bands, using appropriate generators, electrodes, and antennas. Choice of excitation frequency determines many properties and requirements of the plasma, the workpiece, as well as the electrical circuit that is used to deliver electrical energy to the circuit. The performance of the plasma chemical generation and delivery system and the design of the electrical excitation circuitry are interrelated—as the choices of operating voltage, frequency and current levels as well as phase all effect the electron temperature and electron density. Furthermore, choices of electrical excitation and plasma device hardware also determine how a given plasma system responds dynamically to the introduction of new ingredients to the host plasma gas or liquid media and the corresponding dynamic adjustment of the electrical drive, such as via dynamic match networks or adjustments to voltage, current, or excitation frequency to maintain controlled power transfer from the electrical circuit to the plasma.

Referring initially to FIG. **1**, a plasma system **10** is disclosed. The system **10** includes a plasma device **12** that is coupled to a power source **14**, an ionizable media source **16**, and a precursor source **18**. Power source **14** includes any required components for delivering power or matching impedance to plasma device **12**. More particularly, the power source **14** may be any radio frequency generator or other suitable power source capable of producing power to ignite the ionizable media to generate plasma. The precursor source **18** may be a bubbler or a nebulizer, for aerosolizing precursor feedstocks prior to introduction thereof into the device **12**. The precursor source **18** may also be a micro droplet or injector system capable of generating predetermined refined droplet volume of the precursor feedstock from about 1 femtoliter to about 1 nanoliter in volume. The precursor source **18** may also include a microfluidic device, a piezoelectric pump, or an ultrasonic vaporizer.

The system **10** provides a flow of plasma through the device **12** to a workpiece "W" (e.g., tissue). Plasma feedstocks, which include ionizable media and precursor feedstocks, are supplied by the ionizable media source **16** and the precursor source **18**, respectively, to the plasma device **12**. During operation, the precursor feedstock and the ionizable media are provided to the plasma device **12** where the plasma feedstocks are ignited to form plasma effluent containing ions, radicals, photons from the specific excited species and metastables that carry internal energy to drive desired chemical reactions in the workpiece "W" or at the surface thereof. The feedstocks may be mixed upstream from the ignition point or midstream thereof (e.g., at the ignition point) of the plasma effluent, as shown in FIG. **1** and described in more detail below.

The ionizable media source **16** provides ionizable feedstock to the plasma device **12**. The ionizable media source **16** may include a storage tank and a pump (not explicitly shown) and is coupled to the plasma device **12**. The ionizable media may be a liquid or a gas such as argon, helium, neon, krypton, xenon, radon, carbon dioxide, nitrogen, hydrogen, oxygen, etc. and their mixtures, and the like, or a liquid. These and other gases may be initially in a liquid form that is gasified during application.

The precursor source **18** provides precursor feedstock to the plasma device **12**. The precursor feedstock may be either in solid, gaseous or liquid form and may be mixed with the ionizable media in any state, such as solid, liquid (e.g., particulates or droplets), gas, and the combination thereof. The precursor source **18** may include a heater, such that if the precursor feedstock is liquid, it may be heated into gaseous state prior to mixing with the ionizable media. In one embodiment, the precursors may be any chemical species capable of forming reactive species such as ions, electrons, excited-state (e.g., metastable) species, molecular fragments (e.g., radicals) and the like, when ignited by electrical energy from the power source **14** or when undergoing collisions with particles (electrons, photons, or other energy-bearing species of limited and selective chemical reactivity) formed from ionizable media **16**. More specifically, the precursors may include various reactive functional groups, such as acyl halide, alcohol, aldehyde, alkane, alkene, amide, amine, butyl, carboxlic, cyanate, isocyanate, ester, ether, ethyl, halide, haloalkane, hydroxyl, ketone, methyl, nitrate, nitro, nitrile, nitrite, nitroso, peroxide, hydroperoxide, oxygen, hydrogen, nitrogen, and combination thereof. In embodiments, the chemical precursors may be water, halogenoalkanes, such as dichloromethane, tricholoromethane, carbon tetrachloride, difluoromethane, trifluoromethane, carbon tetrafluoride, and the like; peroxides, such as hydrogen peroxide, acetone peroxide, benzoyl peroxide, and the like; alcohols, such as methanol, ethanol, isopropanol, ethylene glycol, propylene glycol, alkalines such as NaOH, KOH, amines, alkyls, alkenes, and the like. Such chemical precursors may be applied in substantially in pure, mixed, or soluble form.

The precursors and their functional groups may be delivered to a surface to react with the surface species (e.g., molecules) of the workpiece "W." In other words, the functional groups may be used to modify or replace existing surface terminations of the workpiece "W." The functional groups react readily with the surface species due to their high reactivity and the reactivity imparted thereto by the plasma. In addition, the functional groups are also reacted within the plasma volume prior to delivering the plasma volume to the workpiece.

Some functional groups generated in the plasma can be reacted in situ to synthesize materials that subsequently form a deposition upon the surface. This deposition may be used for stimulating healing, killing bacteria, increasing hydration (e.g., adding hydroxyl groups to produce carboxyl group at the workpiece), and increasing hydrophilic or hydroscopic properties. In addition, deposition of certain function groups may also allow for encapsulation of the surface to achieve predetermined gas/liquid diffusion, e.g., allowing gas permeation but preventing liquid exchange, to bond or stimulate bonding of surfaces, or as a physically protective layer.

With reference to FIG. **2**, an illustrative embodiment of the plasma device **12** includes a housing **20** enclosing a dielectric inner tube **22** having a proximal end **25** and a distal end **27** configured for the passage of the plasma effluent in either liquid or gaseous form. The plasma device **12** may be utilized as an electrosurgical pencil for application of plasma to tissue and the power source **14** may be an electrosurgical generator that is adapted to supply the device **12** with electrical power at a frequency from about 0.1 MHz to about 1,000 MHz and in another embodiment from about 1 MHz to about 13.6 MHz.

The precursor source **18** and the ionizable media source **16** are coupled to the plasma device **12** via tubing **13***a* and **13***b*, respectively, at a first connection **31**. The tubing **13***a* and **13***b* may be combined into tubing **13***c* to deliver a mixture of the ionizable media and the precursor feedstock to the device **12**. This allows for the plasma feedstocks, e.g., the precursor feedstock and the ionizable gas, to be delivered to the plasma device **12** simultaneously prior to ignition of the mixture therein.

In another embodiment, the ionizable media source **16** and the precursors source **18** may be coupled to the plasma device **12** via the tubing **13***a* and **13***b* at separate connections, e.g., the first connection **31** and a second connection **29**, respectively, such that the mixing of the feedstocks occurs within the inner tube **22** upstream from ignition point. In other words, the plasma feedstocks are mixed proximally of the ignition point, which may be any point between the respective sources **16** and **18** and the plasma device **12**, prior to ignition of the plasma feedstocks to create the desired mix of the plasma effluent species for each specific surface treatment on the workpiece.

In a further embodiment, the plasma feedstocks may be mixed midstream, e.g., at the ignition point or downstream of the plasma effluent, directly into the plasma. More specifically, the first and second connections **31**, **29** may be coupled to the device **12** at the active electrode **23**, such that the precursor feedstocks and the ionizable media are ignited concurrently as they are mixed (FIG. **1**B). It is also envisioned that the ionizable media may be supplied to the device **12** proximally of the active electrode **23**, while the precursor feedstocks are mixed therewith at the ignition point. In other words, the second connection **29** is coupled to the device **12** at the active electrode to achieve mixing that is concurrent with ignition.

In a further illustrative embodiment, the ionizable media may be ignited in an unimixed state and the precursors may be mixed directly into the ignited plasma. Prior to mixing, the plasma feedstocks may be ignited individually. The plasma feedstock is supplied at a predetermined pressure to create a flow of the medium through the device **12**, which aids in the reaction of the plasma feedstocks and produces a plasma effluent.

The device **12** also includes an active electrode **23** that extends around or into tube **22**. The device **12** may also include an optional return electrode **33** disposed on an outer surface of the tube **22**. The electrodes **23** and **33** are capacitively coupled thereto and to the plasma formed within the tube **22**. The electrodes **23** and **33** are formed from a conductive material that may be adapted to assist in the ignition of plasma. In particular, the electrode **23** may have a needle or other pointed shape conducive to maximizing local electric field and forming a predetermined ignition point. The electrodes **23** and **33** are coupled to the power source **14**, such that the energy from the power source **14** may be used to ignite the plasma feedstocks flowing through the inner tube **22**. In another embodiment electrode **23** is connected to a separate ignition circuit (not shown) that transfers energy to cause ignition of the plasma species.

In yet another illustrative embodiment, the inner tube **22** may also be formed from a conductive material. In this embodiment, the inner tube **22** is coupled to the power source **14** and igniting electrical energy is transmitted directly through the inner tube **22**, or between tube **22** and electrode **23**. The inner tube **22** and the electrode **23** may be coupled to the power source **14** through a variety of coupling components, such as wires, cables, antennas and the like. Alternatively, the tube **22** and/or the electrode **23** may be fabricated from conductive materials upon which an insulating layer is formed over at least a portion thereof. In one illustrative embodiment, this may be achieved by forming a metal oxide on a conducting metal or by coating an insulating layer on a conductive material.

The inner tube **22** may be coated by a non-reactive material to reduce plasma species loss through undesired surface reactions. Alternatively, the inner tube **22** may be coated by reactive material that may be removed from the inner tube to create plasma species through tailored plasma driven surface reactions including secondary electron emission or volatilized tube construction material(s). The inner tube **22** may also be coated by an optically reflective material that acts as a means to confine photons generated by the plasma.

The inner tube **22** may have a substantially tubular structure (e.g., cylindrical, granular, etc.). In one embodiment, the distal end **27** may have a high aspect ratio cross-section (e.g., oval, rectangular, etc.). This limits and confines the active plasma volume to provide a flattened plasma effluent. The geometrical confinement of the plasma effluent directs the flow of plasma into open air, imparting a directed hydrodynamic flow of effluent to the workpiece "W" to achieve a highly localized effect on the flow boundary layers. This design provides for enhanced control of the hydrodynamic boundary layers of the plasma effluent and thereby isolates the plasma from the user and minimizes the loss of plasma species (e.g., radicals) to open atmosphere due to an extended length of the boundary layer.

The housing **20** also includes a plasma ignition circuit **24**, which includes input controls **26** having one or more buttons or switches **28** for activating the circuit **24**. The input controls **26** are coupled to the power source **14** and is adapted to activate the energy flow from the power source **14** to the electrodes **23** and **33**. More specifically, the input controls **26** signal the power source **14** to provide a minimum voltage and current suitable for igniting the plasma precursor feedstocks flowing through inner tube **22**, such that the plasma precursor feedstocks are ignited and plasma effluent is ejected from the distal end **27** of the inner tube **22**. This process can be improved upon by enhancing the "Q" factor of the AC power delivery circuit. The activation circuit **24** may be configured either as a toggle switch or a continuous operation switch. In a toggle mode, the plasma effluent is sustained until the switch is toggled. In a continuous mode, the plasma effluent is sustained for as long as the switch is pressed.

In one embodiment, the activation circuit **24** may also be coupled to the ionizable media source **16** and the precursors source **18** such that upon activation of the activation circuit **24**, the power source **14** as well as the flow of plasma feedstocks is also activated simultaneously. Those skilled in the art will appreciate that simultaneous activation may include delaying plasma energy from the power source **14** until the plasma feedstocks reach the inner tube **22**; this may be accomplished by including flow sensors into the tubing **13** and/or the proximal end **25** of the inner tube **22**. Alternatively optical sensors may be used to detect the presence or absence of plasma, or with appropriate optical filtering the presence or absence of one or more particular plasma species. A variety of other upstream and downstream mixing and plasma excitation allows tailoring of the relative concentrations of the various plasma species.

FIG. **3** illustrates a method for operating the system **10** according to the present disclosure. In step **100**, once the plasma device **12** is brought in proximity with the workpiece "W," the activation circuit **24** is activated to commence the flow of the plasma feedstocks from the precursors source **18** and the ionizable media source **16**, respectively. The plasma feedstocks are fed to the plasma device **12**, where they are mixed upstream prior to ignition thereof or midstream, e.g., in the ignition region. In step **102**, the plasma device **12** signals the power source **14** to supply sufficient energy to ignite the mixed plasma feedstocks. The plasma feedstocks are ignited and plasma effluent is sustained by electrical energy. The ignition induces a variety of physical and chemical reactions in the feedstocks, such as dissociation (e.g., breaking up of molecular components into smaller parts) of the feedstocks into highly reactive species (e.g., radicals, ions, etc.). This plasma environment induces chemical changes to the precursors via a multitude of reactions, including direct electron and photon irradiation directly from the ignited plasma. These chemical changes are contrasted to plasma systems that inject precursors downstream from the active plasma volume in that the present disclosure creates said species in much higher densities and at much higher rates. In step **104**, the plasma effluent flows out of the distal end **27** of the inner tube **22** to the workpiece "W." The delivered plasma volume includes various reactive species, such as the functional groups of the precursor feedstock, which are deposited unto the workpiece "W" to react with substitutents thereof (e.g., molecules).

FIG. **4** illustrates another illustrative embodiment of a plasma system **110**. The system **110** includes a controller **32**, which may be a microcontroller, microprocessor or any other suitable logic circuit. The controller **32** may be incorporated into the power source **14**. The controller **32** may be coupled to the input controls **26** for controlling the system **110**. More specifically, the controller **32** is coupled to the power source **14**, ionizable media source **16**, and first and second regulator valves **34** and **36**. The first regulator valve **34** is coupled to the ionizable media source **16** and controls the flow of the ionizable medium to the plasma device **12**. The second regulator valve **36** is coupled to the precursor source **18** and controls the flow of the precursors to the plasma device **12**.

As shown in FIG. **4**, the device **12** includes an active electrode **43** and a return electrode **45** disposed about an outer surface of tube **22**. The electrodes **43** are capacitively coupled to the ionizable media and precursor mix in the tube **22** the extent of their relative positions defining the active plasma volume. The operation of the system **110** may be controlled through the input controls **26**. The user may initiate the flow of ionizable media source **16** via the input controls **26**. The input signal is then processed by the controller **32**, which opens the first and second regulator valves **34** and **36** to open the flow of ionizable media and the precursor feedstock. The first and second regulator valves **34** and **36** may be either opened consecutively or simultaneously. The controller **50** then activates the power source **14** in unison with the flow from the first and second regulator valves **34** and **36** as needed to produce metastable plasma.

FIG. **5** shows another embodiment of a plasma system **120** having multiple precursor sources **40***a*, **40***b* and **40***c*, each including various types or combinations of precursors. Multiple precursors may be embodied using any of the above-illustrated containers and/or delivery devices. The input controls **26** may include multiple buttons or switches **41***a*, **41***b* and **41***c* for activating each of the precursor sources **40***a*, **40***b* and **40***c*, respectively. In another embodiment, the input controls **26** may be located at any location in the system **120** where manual operation is desired or in the case of automated systems RF power, flow of ionizable media, and chemical precursors may be controlled automatically by the controller **32** based on a feedback algorithm.

EXAMPLES

Argon gas was mixed with CCl_4 and ignited within a plasma activation device. Spectra were obtained for the plasma inside outside device as illustrated by the dashed and solid graphs, respectively in FIG. **6**. The graphs illustrate generation of various chemical species as a result of the plasma being produced from an ionizable media and a chemical precursor. The intensity of the various emissions correspond to relative concentrations of different chemical species and they show that as the plasma flows into open air, there is a decrease of the density of some species but an increase in the density in other species. This is due to the plasma mixing with nitrogen, oxygen, carbon dioxide and other constituent gases of air. This exemplar plasma was used to successfully to remove tissue material.

Although the illustrative embodiments of the present disclosure have been described herein with reference to the accompanying drawings, it is to be understood that the disclosure is not limited to those precise embodiments, and that various other changes and modifications may be effected therein by one skilled in the art without departing from the scope or spirit of the disclosure. In particular, as discussed above this allows the tailoring of the relative populations of plasma species to meet needs for the specific process desired on the workpiece surface or in the volume of the reactive plasma.

What is claimed is:

1. An electro surgical system for application of plasma to tissue comprising:
- an electro surgical pencil including:
  - a housing including a dielectric tube having an optically reflective coating on an inner surface of the dielectric tube; and
  - a removable reactive material coated on the inner surface; and
  - an active electrode;
- an ionizable media source configured to supply ionizable media to the electro surgical pencil;
- a precursor source configured to supply at least one precursor feedstock to electro surgical pencil; and
- a power source coupled to the active electrode and configured to ignite the ionizable media, the removable reactive material, and the precursor feedstock at the electro surgical pencil to form a plasma volume, wherein the at least one precursor feedstock and the ionizable media are mixed and ignited concurrently.

2. The electrosurgical system according to claim **1**, further comprising a microcontroller for controlling a flow of the ionizable media and the precursor feedstock.

3. The electrosurgical system according to claim **2**, further comprising a first regulator valve coupled to the ionizable media source and a second regulator valve coupled to the precursor source, wherein the first and second regulator valves are coupled to the microcontroller.

4. The electrosurgical system according to claim **1**, wherein the ionizable media is selected from the group consisting of argon, helium, neon, krypton, xenon, radon, nitrogen, hydrogen, oxygen, carbon dioxide, nitrous oxide, and mixtures thereof.

5. The electrosurgical system according to claim **1**, wherein the at least one precursor feedstock is a compound having a functional group selected from the group consisting of acyl halide, alcohol, aldehyde, alkane, alkene, amide, amine, butyl, carboxlic, cyanate, isocyanate, ester, ether, ethyl, halide, haloalkane, hydroxyl, ketone, methyl, nitrate, nitro, nitrile, nitrite, nitroso, peroxide, hydroperoxide, oxygen, hydrogen, nitrogen, and combinations thereof.

6. The electrosurgical system according to claim **1**, wherein the at least one precursor feedstock is selected from the group consisting of water, haloalkanes, peroxides, alcohols, amines, alkyls, alkenes, alkalines, and combinations thereof.

7. The electrosurgical system according to claim **1**, wherein the precursor source includes at least one of a bubbler, a microfluidic device, a nebulizer, a micropump, a piezoelectric pump, or an ultrasonic vaporizer.

8. The electrosurgical system according to claim **1**, wherein the electrosurgical pencil includes a return electrode disposed on an outer surface of the dielectric tube.

9. The electrosurgical system according to claim **8**, wherein the active and the return electrodes are capacitively coupled to the plasma volume.

10. An electro surgical system for application of plasma to tissue including:

an electro surgical pencil including:

a housing including a dielectric tube having an optically reflective coating on an inner surface of the dielectric tube; and

a removable reactive material coated on the inner surface; and

an active electrode;

an ionizable media source configured to supply ionizable media to the electro surgical pencil;

a plurality of precursor sources, each of the precursor sources configured to supply at least one precursor feedstock to the electro surgical pencil; and

a power source coupled to the active electrode and configured to ignite the ionizable media, the removable reactive material, and the precursor feedstock at the electro surgical pencil to form a plasma volume, wherein the at least one precursor feedstock and the ionizable media are mixed and ignited concurrently.

11. The electrosurgical system according to claim **10**, wherein the electrosurgical pencil includes input controls to activate each of the plurality of the precursor sources individually.

12. The electrosurgical system according to claim **10**, further comprising a microcontroller for controlling a flow of the ionizable media and at least one of the precursor feedstock.

13. The electrosurgical system according to claim **1**, wherein the electrosurgical pencil is a hand-held electrosurgical pencil, the power source is an electrosurgical generator, and the plasma volume is configured to at least one of substitute or replace surface-terminating species of biological tissue surfaces.

14. The electrosurgical system according to claim **10**, wherein the electrosurgical pencil is a hand-held electrosurgical pencil, the power source is an electrosurgical generator, and the plasma volume is configured to at least one of substitute or replace surface-terminating species of biological tissue surfaces.

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